

# Kugel's Artery

## An Anatomical and Angiographic Study Using a New Technique

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*In this study, we tried to resolve the confusion in the literature regarding the existence and course of Kugel's artery.*

*With the aid of a new technique, we studied 100 human hearts ex vivo by radiography and by direct observation through dissection, to demonstrate anatomical and post-mortem angiographic findings of Kugel's artery.*

*Kugel's artery was found in only 6 hearts out of 100 (6%). It originated from the proximal left circumflex artery and ended in the right coronary artery in 2 cases; from the right coronary artery and ended in the same artery in 2 cases; from the left circumflex artery and ended in the same artery in 1 case; and from the right coronary artery through the sinus node artery, ending in the left circumflex artery, in 1 case. In all 100 hearts, an anastomotic network of small atrial branches was found in the same area (lower portion of the interatrial septum), connecting the large vessels indirectly. Branches of the sinus node artery in all hearts, and of the atrioventricular node artery in 66 hearts, participated in this network. Our procedure showed the detailed course of Kugel's artery and its course independent from the atrioventricular node artery and from the anastomotic network.*

*In conclusion, in all cases an anastomotic network of small atrial branches courses through the lower interatrial septum and connects indirectly the proximal and distal ends of the larger coronary arteries. Kugel's artery provides an additional direct arterial anastomosis in the same area in 6% of the hearts. (Tex Heart Inst J 2004;31:267-70)*

### Key words:

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In 1927, M.A. Kugel<sup>1</sup> described an atrial artery that arose from the proximal left circumflex artery (LCx) or from its branches, coursed through the lower part of the interatrial septum, and in most of his cases (66%) anastomosed directly or through its branches with the distal right coronary artery (RCA). In the rest of his cases, the same artery formed anastomoses with the proximal RCA (26%) or with branches from the anterior portion of the LCx and RCA and the posterior portion of the LCx (8%). He called this artery "arteria anastomotica auricularis magna" because of its large caliber, the apparent importance of its anastomotic role, and its consistent occurrence at this site.

James<sup>2</sup> and McAlpin<sup>3</sup> did not accept the existence of such an artery in their anatomical studies. Instead, they described small atrial branches that arose from either the LCx or the RCA, or even from both arteries, and connected with one another or with other small atrial branches from the surrounding area, then coursed posteriorly to the base of the interatrial septum and anastomosed with the atrioventricular node (AVN) artery. Although both James and McAlpin described an anastomotic network without accepting the existence of an artery, they applied the term "Kugel's artery" to this network. Moreover, they did not indicate the frequency of the network.

On the other hand, angiographic studies have shown the existence in the same area of a large atrial artery that arises from the RCA or the LCx, or through the sinus node artery, and anastomoses with the AVN artery in various percentages (3.6%,<sup>4</sup> 4.5%,<sup>5</sup> and 6%<sup>6</sup>) of cases. These authors, however, emphasize that this artery was found only in cases of severe atherosclerosis of the large coronary arteries. In the literature mentioned, Kugel's artery was not simple to demonstrate post-mortem,<sup>7</sup> and was extremely difficult to see in coronary arteriograms in vivo.<sup>4,6,8</sup>

Our study, using a large series of specimens and a new technique, attempts to resolve the confusion in the literature regarding the existence of Kugel's artery, its origin, its ending, and its relationship to the AVN artery. It also attempts to give details regarding whether an anastomotic network of small atrial arteries exists in the same area and what its relation to Kugel's artery and the AVN artery might be.

These new anatomical findings may become useful to physicians who engage in diagnostic and therapeutic procedures that involve this area of the heart.

## Materials and Methods

This study was performed in 100 normal human hearts obtained from subjects (28 females and 72 males) less than 40 years old, all victims of various accidents or noncardiac diseases.

A different-colored radiopaque medium ( $\text{BaSO}_4$ ), was injected into each coronary artery. Both coronary arteries were injected simultaneously at a pressure of 100 to 150 mmHg, depending on the size of the heart, in order to render the arteries and their branches clearly visible to the naked eye. We took care to avoid occlusion of the atrial branches originating from the beginning of the coronary arteries. In addition, radiographic films were made in anteroposterior, posteroanterior, lateral, and left and right anterior oblique projections. After that, the hearts were fixed in 10% neutral formalin for about 2 weeks. The hearts were then sectioned parallel to the atrioventricular sulcus, 1 cm above and  $\frac{1}{2}$  cm below it, which divided the heart into 3 parts. The middle part included the pulmonary artery, the aorta with the coronary arteries, the atrioventricular valves, the base of the interatrial septum, and the adjacent part of the interventricular septum. This slice was selected for radiographic imaging, which was performed by placing the specimen on radiographic film and irradiating it with a perpendicular X-ray beam. This new radiologic view was the most appropriate one to give details about the origin, course, distribution, and terminus of Kugel's artery and the AVN artery, as well as the connection of small atrial branches. In this manner, we avoided mistaking the X-ray view of Kugel's artery for either the AVN artery or the anastomotic network of the vessels distributed in the same area. Finally, the middle part of all the hearts was dissected and injected with the colored medium. The coronary arteries, from their origin to their most visible end, were examined by the naked eye and with the use of a magnifying lens.

The length of the artery was measured from its origin to the end. The diameter of the arterial lumen was measured in cross-section under a microscope, from a sample taken from the middle of the vessel's length.

## Results

Among the 100 hearts studied, 86 were right dominant, 12 were left dominant, and 2 were balanced. The terms "right dominant" and "left dominant" are used here in a topographical sense, according to whether the RCA or LCx gave rise to the posterior de-

scending artery. The term "balanced" implies that both coronary arteries gave rise to a posterior descending branch. The sinus node artery arose from the RCA in 60 cases, from the LCx in 36 cases, and from both in 4 cases.

In 6 out of 100 hearts (6%), a Kugel's artery was found to connect the proximal RCA or the LCx—either directly or through the sinus node artery—with the distal arterial segment, after it crossed the crux (the meeting point of the atria, ventricles, and septa). Kugel's artery gave rise to small branches to the surrounding area and took a course independent from that of the AVN artery.

In 2 right-dominant hearts, Kugel's artery arose from the proximal LCx 6 mm or (in the 2nd case) 11 mm from its opening. These arteries traveled through the epicardial fat in the atrioventricular groove to the right of the aorta and behind it, to meet the interatrial septum near its junction with the interventricular septum. Then they proceeded posteriorly through the lower portion of the interatrial septum from left to right, passed to the right of the coronary sinus opening, and met the RCA directly at a distance of 4 mm or (in the 2nd case) 7 mm to the right of the crux, thereby making an intercoronary connection (Fig. 1).

In 2 other right-dominant hearts, Kugel's artery arose from the proximal RCA 3 mm or (in the 2nd case) 8 mm from its opening. These arteries traveled through the epicardial fat in the atrioventricular groove to the left of the aorta and behind it, to meet the interatrial septum near its junction with the interventricular septum. Subsequently, they coursed posteriorly through the lower portion of the interatrial septum to its right, passed to the right of the coronary sinus orifice, and met the distal RCA directly at a distance of 3 mm or (in the 2nd case) 6 mm to the right of the crux, thereby making an intracoronary connection.

In 1 left-dominant heart, Kugel's artery arose from the proximal LCx 5 mm from its opening. It traveled through the epicardial fat in the atrioventricular groove to the right of the aorta and behind it, to meet the interatrial septum near its junction with the interventricular septum. Then it proceeded posteriorly through the lower portion of the interatrial septum from the left, passed under the coronary sinus, and met the LCx directly at a distance of 5 mm to the left of the crux, thereby making an intracoronary connection.

In the last heart (a left-dominant one), Kugel's artery arose 10 mm from the beginning of the sinus node artery, which originated 14 mm from the orifice of the RCA. It traveled through the epicardial fat in the atrioventricular groove to the left of the aorta and behind it, to meet the interatrial septum near its junction with the interventricular septum. After that, it

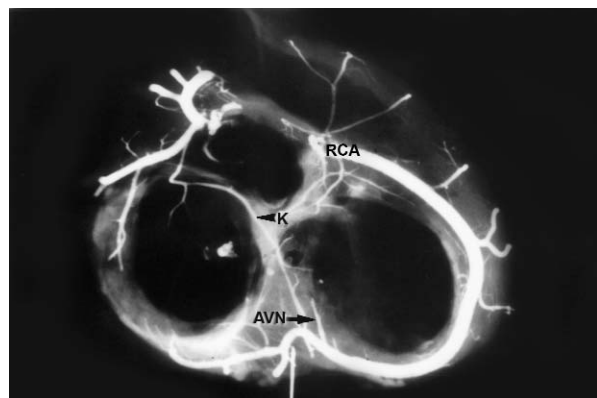
proceeded posteriorly through the lower part of the interatrial septum from right to left, passed under the coronary sinus, and connected directly to the LCx 7 mm to the left of the crux, thereby making an inter-coronary connection.

Kugel's artery originated from the LCx in 3 cases and from the RCA in the other 3 cases (in one of those through the sinus node artery).

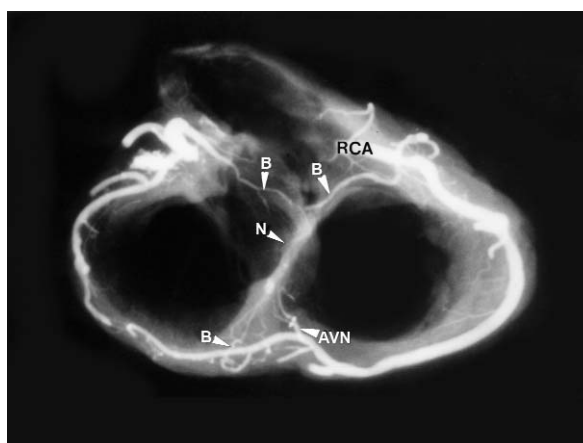
Kugel's artery was found in 2 out of 12 cases (17%) of left-dominant hearts and in 4 out of 86 cases (5%) of right-dominant hearts.

Kugel's artery ranged from 37 to 58 mm in length and from 0.8 to 1.1 mm in luminal diameter.

It is worth noting that, in all hearts examined, we found an anastomotic network of variant size connecting the coronary trunks indirectly, in the lower part of the interatrial septum, mainly in its right side. This network consisted of either small or sometimes larger atrial branches that originated from the proximal LCx and RCA, connected behind the aorta, and traveled posteriorly to give rise to anastomoses to small atrial branches, which originated from the artery crossing the crux (Fig. 2). The sinus node artery contributed to the formation of this network, with branches of different sizes. In 66 cases, the AVN artery contributed also to the network, thereby enlarging it. In some cases, the participation of very small branches from the superior descending artery was noted. The anastomotic network provided important branches to the AVN area.



**Fig. 1** Superior view of the middle part of a normal right-dominant heart containing the arteries and their branches that course through the atrioventricular groove and the lower portion of the interatrial septum. The arteriogram shows that Kugel's artery (K) directly connects the proximal left circumflex artery with the distal right coronary artery (RCA) near the crux (intercoronary connection). Kugel's artery distributes branches throughout its course. The independent atrioventricular node (AVN) artery can also be seen. Furthermore, atrial branches forming an anastomotic network are shown (more details in Fig. 2). The needle (at bottom of image) shows the crux.



**Fig. 2** Superior view of the middle part of a normal right-dominant heart containing the arteries and their branches that course through the atrioventricular groove and the lower portion of the interatrial septum. The arteriogram shows that atrial branches (B) originating from the proximal left circumflex artery and the right coronary artery (RCA) connect and form an anastomotic network (N). It also shows the contribution of the atrioventricular node (AVN) artery to the network. Note that the atrial branches shown in this arteriogram appear to be larger than those in Figure 1, because we magnified this figure to better demonstrate the network and also because the absence of Kugel's artery makes them larger.

## Discussion

We succeeded in using a new technique to find, and then describe in detail, vascular courses in the lower part of the interatrial septum. In all of our cases, we observed anastomotic networks of various sizes. In addition, in 6 of the 100 hearts, we found a Kugel's artery in the same area.

We described as a Kugel's artery an atrial artery that connected directly or through the sinus node artery the proximal part of the LCx or the RCA with the distal part of the vessel where it crossed the crux. This artery is long and wide, and suitably fulfills the 4 initial descriptive terms given by Kugel: "arteria anastomotica auricularis magna." Most of the authors cited herein<sup>2,3,6-8</sup> have not accepted the term "artery" because they found small atrial branches, but not a vessel so large in diameter as an artery in the lower part of the interatrial septum. It is strange, however, that they used the term Kugel's artery, despite the fact that they described only an anastomotic network in this area.

We found only 6 Kugel's arteries out of 100 normal hearts (6%). Similar percentages ranging between 3.6% and 6%, albeit in patients with severe atherosclerotic heart disease, have been reported in the literature, in 3 coronary angiographic studies.<sup>4-6</sup> On the other hand, in anatomical studies, the percentage ranged between 40%<sup>9</sup> and 66%.<sup>1</sup> We believe that these increased percentages probably included cases

with a large anastomotic network. It is hard to explain why other authors did not report any percentages in their studies.<sup>2,3,8</sup>

Kugel's arteries originated from the LCx in 3 hearts and from the RCA in the other 3 (via the sinus node artery in 1 of these last). Our results, in accordance with previous publications,<sup>2,3,5,6,8,10</sup> clearly demonstrate that this artery does not have a standard point of origin.

In our 6 hearts, Kugel's artery was connected directly with the distal artery after it crossed the crux, keeping a course independent from the AVN artery. The same finding has been described in a case report.<sup>10</sup> Kugel<sup>1</sup> reported that in some cases his artery connected directly with the distal right coronary artery, while in all other cases it connected via the AVN artery. Most of the authors who have reported finding Kugel's artery in their anatomical and angiographic studies have mentioned its indirect connection with the artery that crosses the crux, always through the AVN.<sup>2-6,8</sup>

Kugel's artery is difficult to demonstrate in postmortem angiography,<sup>7</sup> and it is also difficult to see in vivo, in the usual coronary arteriographic projections.<sup>3,8,10</sup> However, with our technique, we succeeded in demonstrating clearly for the 1st time this artery in postmortem angiograms. We also believe that Kugel's artery will be easy to demonstrate in vivo if the right oblique projection is used for the right arteriogram and the left lateral projection for the left arteriogram. In both projections, a cephalad angle will often help to bring the artery into the middle of the projection, parallel to the AVN artery, thereby avoiding overlap with the vessels in the atrioventricular groove.

The anastomotic network was found in all 100 hearts, connecting indirectly the proximal and distal parts of the large coronary arteries—via the AVN artery in 66 cases and, in the rest, via small branches from the artery that crossed the crux. This type of connection via the AVN artery has been described in most of the studies.<sup>2-6</sup> The sinus node artery or its branches contributed to the formation of this network, an observation that has been mentioned by others.<sup>11,12</sup> We observed the participation of the right superior descending artery, but we did not describe this in detail because of the small number of cases in which it was found. In 1 study, the participation of this artery was found to be as high as 40%.<sup>9</sup>

We believe that our technique will render satisfactory the postmortem angiographic demonstration of the network in normal hearts, but in vivo arteriographic demonstration of the network, unlike that of Kugel's artery, will remain very difficult due to the small size of the vessels.

In other studies,<sup>3-6</sup> all these inter- and intracoronary anastomoses tended to be larger in hearts with stenotic lesions of the major epicardial coronary arteries.

Since both Kugel's artery and the anastomotic network originate from the beginning of the coronary trunks, they have to be taken into consideration in many surgical procedures involving the aortic root.<sup>13</sup> Moreover, interventional cardiologists who perform procedures involving the lower part of the interatrial septum, such as radiofrequency ablation and biven-tricular pacemaker insertion, should be aware of the potential risk of damaging these important anastomotic branches.

In conclusion, an anastomotic network of small atrial branches courses through the lower part of the interatrial septum and in all cases indirectly connects the proximal to the distal ends of the larger coronary arteries, while Kugel's artery, in 6% of the cases, provides a direct arterial anastomosis in the same area. The knowledge from these findings is important for anatomists, cardiologists, and cardiac surgeons.

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